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Correlation Between Boron Contents of Soils and Wheat Plants (*Triticum* spp.) in The Cukurova Plain in Turkey

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In this study, the correlation between boron contents of soil and boron contents of the wheat (*Triticum* spp.) in the Cukurova Region of Turkey has been reported. The soil samples were taken from the root area of the plants and collected leafs and grains samples of the same plants were analyzed for boron contents. The leaf samples taken during the stem elongation time and the grain samples taken at the maturation time were also analyzed. The boron contents of soil of samples were between 0.96 and 2.69 mg kg^{-1}, but the boron contents of soil of some samples were measured under the critical level which is 1.00 mg kg^{-1}. Whereas boron contents of leaves of wheat samples were obtained from 1.62 to 18.73 mg kg^{-1} and the boron contents of grain of wheat samples were obtained from 2.6 to 9.1 mg kg^{-1}. There are an inverse relation between boron contents of soil, boron contents of leaves and boron contents of grain, respectively. Also, correlation between boron contents of soil and boron contents of leaves is significant at the 0.01 level according to statistical analysis. An addition, linear regression analysis was performed between dependent variable (boron contents of soil), independent variable (boron contents of leaves and boron contents of grain). F test and t- test using ANOVA was shown that significant values of each test are very practicable.

Key Words: Soil characteristic, Boron, Micronutrient elements, Mineral deficiency.

INTRODUCTION

Agricultural productivity in many arid and semiarid regions of the world is threatened by the occurrence of salt-affected soils. Thus, improved management practices are needed to maintain or increase the productivity of saline-sodic soils[1]. Facilitation among the plants occurs in natural ecosystems as well as in agroecosystems and takes place when plants ameliorate their neighbours by increasing growth or survival. Facilitative root interactions are most likely to be of importance in nutrient-poor saline-sodic soils due to the critical inter specific competition for

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plant growth factors[2]. Boron is often found in high concentrations in association with saline-sodic soil. Boron is removed more slowly than salt ions during the leaching and may therefore still be present at excessive concentrations in some reclaimed soils[3]. Many elements of the periodic table are trace elements. Although some trace elements are essential to life, some of them have toxic effects in high concentrations[4]. Boron in the form of various oxides is removed from the atmosphere by precipitation and deposition fairly rapidly (a half-life measured in days). Whether *via* atmospheric deposition, precipitation or weathering of boron-containing rocks, boron can be expected to migrate to the water column where it may hydrolyzed to its weak acid form. Once in the water column the only significant factor that will affect its fate is possible adsorption to soils and sediment. The adsorption process is not well predicted and will need to be determined for each sediment type being considered. Besides, the oral reference dose of human for boron is 0.09 mg kg^{-1} d^{-1} and is based on testicular atrophy and spermatogenesis effect. An ambient water quality criterion of 750 ppb boron in water has been suggested based on long-term irrigation of sensitive crops[5]. The chemical composition, behaviour of plant nutrients and heavy metals in soil depend on chemical properties and composition of the soil matrix. Thus, the variation of composition in the soil matrix may lead to significant variation of composition and behaviour of soil nutrients and heavy metals. The distribution of a specific element or a micro element in the solid phase can be important for controlling its initial rate of leaching. Elements that are attached on particle surfaces will be more readily accessible to the soil solution[6]. As staple crops contribute substantially to daily calories intake among people in developing countries, there has been a resurgence of interest in addressing human malnutrition through breeding of staple crops, specifically to address micronutrient malnutrition[7-10].

The conducted studies in recent years showed the important role of micro elements in human and plant nourishment. The studies made especially on zinc point out that the problem of zinc deficiency is in serious condition in Turkey. Insufficient content of micronutrient elements in soil has a negative impact on the development of crops, which, in turn, affects human health. Micro element deficiencies like zinc and iron bring out some serious health problems especially in children at developing age. In this respect, micronutrient elements exhibit a profound significance for the condition of human health as much as they do for a successful production of crops. The essentiality of boron to animals and human beings has not been identified, but it is essential for plants. Boron deficiency affects plant growth and yield quality, but substantial amounts of boron are toxic to plants and reduce plant yield[11]. Boron, an essential trace element, is often applied to agricultural and horticultural crops. Boron contents does appear to play a critical role in cell wall structure[12,13]. Boron fertilizer recommendations include foliar or soil-applied boron for alfalfa (*Medicago sativa* L.), cole crops, cotton (*Gossypium hirsutum* L.), peanuts (*Arachis hypogaea* L.) and fruit trees at rates ranging[14,15] from 0.4 to 3.4 kg B ha^{-1}. The research results have shown that boron responses to foliar or soil-applied boron are common in some field crops. For example, foliar application of boron at rates from 0.3 to 1.3 kg boron ha^{-1} increased yield or seed weight of soybean (*Glycine max* L.) and cotton[16-18]. Boron is distributed in various soil components, including soil solution, organic matter (OM) and minerals. Boron contents of soil solution is readily available for plant uptake, but this pool constitutes < 3 % of total boron contents of soil[19]. Maintaining boron contents of soil solution is important for plant nutrition[20,21] and it is controlled by there are very little study about boron in the Turkey. It is well-known that excess boron contents of soil is not removed as readily, when being leached as excess chloride and sulphate salts. Bingham *et al.*[22] reported that the volume of water needed to reduce boron from the toxic to non-toxic level is two to three folds higher than that needed for a comparable reduction in Cl^-. The objectives of this study: (i) was to determine the soil boron content of wheat production field in Cukurova region; (ii) was to examine correlation among boron contents of soil, boron contents of leaves and boron contents of grain.

EXPERIMENTAL

Description of the area: This study carried out in the Cukurova region in the East Mediterranean region of Turkey. Cukurova region is one of the most important agricultural areas of Turkey. The area is characterized by xeric climate. The average amount of annual rainfall is 67.08 cm and potential total evaporation is 153.60 cm. The mean annual air temperature is 19.1 ºC. The mean annual soil temperature at 50 cm depth is 20.8 ºC. All the soils are xeric moist regime. The vegetations in the study area are grasses, cereal and leguminous crops. The vegetation was dominated by cereal and leguminous grasses. Wheat, cotton, maize, grape and soybean have been commonly cultivated in Cukurova plain as industrial crops in Turkey.

In this study, 30 leaves samples, 30 grain samples and 30 soil samples in 2006 were collected to research from wheat (*Triticum* spp) fields in Cukurova Region of Turkey. Plants were sampled during growing (heading) to determine boron contents of leaves. Grain samples were taken in the harvest season to determine boron contents of grain. Soil samples were taken from 0-30 from roots region for laboratory analysis. Soil samples were collected from 0-30 cm depth and air dried to pass a 2 mm siever. The particle size distribution of each sample was determined by the pipette method[23] after removal of organic matter and carbonates. The pH was measured on saturation extracts (Radiometer PHM 82 standard pH meter). Organic carbon was measured by using a modified Walkley-Black procedure[24]. Carbonate content was determined by the Scheibler calcimeter method[25]. Cation-exchange capacity was measured with Mg saturation followed by NH_4 substitution[23]. Available P_2O_5 analysis was carried out by following method. Samples were homogenized directly with 0.1 M sodium acetate buffer at 41 ºC and then centrifuged at 30,000 g. Enzyme extracts were incubated for 1 h at 30 1C and phosphate content was determined to by spectrophoto-meter (Shimadzu UV-VIS 1201) at 405 nm[26]. Extractable boron by the citrate dithionite-bicarbonate method was carried out by Kick *et al.*[27].

RESULTS AND DISCUSSION

Some chemical properties of soils: Some selected physical and chemical properties of soils were presented in Table-1[28]. $CaCO_3$ and organic matter content of soil were observed between 16.0 and 21.0 %, and 1.46 and 2.33 %, respectively. The cation exchange capacity (CEC) values change between 21.24 cmol kg^{-1} and 38.02 cmol kg^{-1}. Also soil pH has changed between 7.50 and 7.99. The lowest utilizable P_2O_5 content was observed in sample number 23 as 16 kg ha^{-1}. The highest amount of utilizable P_2O_5 was 179 kg ha^{-1} in sample number 6 while the amount of utilizable P_2O_5 changes between 16 and 179 kg ha^{-1}. It is believed that the excess amount of utilizable P_2O_5 in soil caused by overdose application of fertilizer. The excess amount of utilizable P_2O_5 content seems to have a disadvantage for micro-elements uptake from soil[10,29].

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN STUDY AREA

Sample	$CaCO_3$ (%)	Organic matter	CEC (cmol kg^{-1})	pH (1/1)	P_2O_5 (kg^{-1}hectare)	Particle-size < 2 mm (%)		
						Clay	Silt	Sand
1	16.0	2.33	26.04	7.50	125	31.9	43.0	25.1
2	17.0	2.05	28.66	7.64	49	31.1	46.1	22.8
3	16.0	2.02	29.77	7.71	51	30.6	44.8	24.6
4	16.0	1.83	25.04	7.58	130	32.2	41.9	25.9
5	16.0	1.71	29.63	7.62	70	33.2	43.7	23.1
6	16.0	1.49	21.24	7.57	179	23.1	25.3	51.6
7	19.0	1.90	38.02	7.69	64	34.4	49.2	16.4
8	21.0	1.83	30.62	7.75	68	32.2	45.9	21.9
9	18.0	1.73	32.22	7.76	47	40.8	48.7	10.5
10	21.0	1.90	30.83	7.73	65	38.7	49.7	11.6
11	19.0	2.08	30.87	7.68	25	37.1	51.7	11.2
12	18.0	2.08	29.94	7.71	66	37.1	52.3	10.6
13	18.0	2.14	30.91	7.74	38	39.5	47.9	12.6
14	17.0	2.24	35.50	7.64	122	40.2	48.6	11.2
15	18.0	2.21	33.08	7.71	122	39.1	49.7	11.2
16	18.0	1.96	34.75	7.66	74	39.1	49.2	11.7
17	18.0	2.17	36.33	7.65	69	40.8	48.2	11.0
18	18.0	1.74	34.72	7.76	66	41.4	48.9	9.7
19	18.0	1.99	33.08	7.68	81	39.6	49.3	11.1
20	17.0	1.99	33.55	7.72	105	37.2	50.5	12.3
21	18.0	1.90	33.80	7.71	49	41.7	48.3	10.0
22	18.0	1.86	33.66	7.77	56	41.8	47.5	10.7
23	19.0	1.99	30.88	7.74	16	39.0	48.2	12.8
24	21.0	2.05	30.80	7.72	72	34.7	50.6	14.7
25	20.0	1.71	33.30	7.67	60	37.3	48.9	13.8
26	21.0	1.46	31.72	7.63	29	38.4	53.7	7.9
27	21.0	1.65	31.63	7.50	46	35.1	50.5	14.4
28	21.0	1.27	31.51	7.59	60	36.4	52.0	11.6
29	18.0	1.65	32.60	7.99	51	36.1	47.2	16.7
30	17.0	1.68	31.60	7.72	31	36.1	44.0	19.9
SD	1.68	0.25	3.34	0.09	36.03	4.16	5.04	8.55

Boron contents of soils: Boron contents of soils were given in Table-2. Boron contents of soil samples were determined as low ranging from 0.96 to 2.69 mg kg^{-1} according to results of chemical analysis. Boron contents of all soil samples were appeared to be higher than boron critical level being 1.00 mg kg^{-1} except for sample number 11. The sample number 11 have had the lowest amount of boron content being 0.96 mg kg^{-1} and the sample number 28 have had the highest amount of boron content being 2.69 mg kg^{-1}. The high boron content may be associated with chemical composition of parent material. Also the high boron contents may be associated with irrigation waters. It is known that soil parent material and irrigation waters have an effect on chemical properties of soil[11,30]. A variety of factors such as pH, organic matter, clay minerals, Fe and Al oxides, carbonates and tillage management may change the content of extractable boron and transformations among different soil boron fractions[21].

TABLE-2
BORON CONTENTS OF SOIL (BOS), BORON CONTENTS OF LEAVES (BOL), BORON CONTENTS OF GRAIN (BOG) AND 1000 KERNEL

Sample no.	BOS (mg kg^{-1})	BOL (mg kg^{-1})	BOG (mg kg^{-1})	1000 kernel (g)	Variety
1	2.09	13.57	5.1	43.59	Adana-99
2	2.20	16.15	4.5	43.74	Ceyhan-99
3	1.42	13.57	3.5	40.14	Ceyhan-99
4	1.82	14.21	3.4	46.15	Adana-99
5	1.85	13.57	2.9	41.91	Adana-99
6	2.47	11.95	2.6	40.86	Adana-99
7	1.57	11.95	4.5	44.48	Adana-99
8	1.65	17.44	3.4	41.60	Adana-99
9	2.24	7.75	4.1	49.74	Fuatbey-2000
10	1.99	10.98	4.0	40.93	Pandas
11	0.96	11.95	5.6	40.07	Pandas
12	1.47	8.72	4.6	52.26	Fuatbey-2000
13	1.48	11.95	5.6	51.08	Amanos-97
14	2.08	12.27	4.1	40.87	Amanos-97
15	1.89	11.95	5.1	39.83	Adana-99
16	1.77	17.12	5.6	40.86	Ceyhan-99
17	1.56	18.73	4.1	42.12	Pandas
18	1.21	12.60	5.1	48.31	Fuatbey-2000
19	2.05	13.24	5.6	46.49	Amanos-97
20	2.04	3.87	6.1	41.44	Karatopak
21	2.00	3.23	6.6	45.07	Osmaniyem
22	1.90	5.17	5.6	44.30	Seri-2
23	2.15	1.62	7.1	37.30	Seri-2
24	2.27	4.52	7.1	34.83	Milan/Amsel
25	2.34	5.17	4.1	39.55	/Kauz
26	2.61	6.14	3.5	39.34	Adana-99
27	2.64	5.17	4.6	43.09	Fiscal
28	2.69	5.17	4.1	45.06	Fiscal
29	2.14	4.52	9.1	54.43	MexicalI.75
30	1.92	3.55	9.1	54.80	Amanos-97

Boron contents of leaves: Boron contents of leaf samples were given in Table-2. boron contents of leaf samples were changed between 1.62 and 18.73 mg kg^{-1} according to results of chemical analysis. Boron contents of all sample leaves are appeared to be lower than critical level being 20 mg kg^{-1}. Boron contents of leaves sample number 22 was determined as the lowest (1.62 mg kg^{-1}). Also, boron contents of soil sample number 22 was determined as low (1.90 mg kg^{-1}). Other hands, boron content of sample number 17 was determined as the highest (18.73 mg kg^{-1}). As seen in the study, boron contents of soil does have a direct effect on boron contents of leaves. Correlation between boron contents of soil and leaves are given in Figs. 2 and 3. There are an inverse relation between boron contents of leaves and boron contents of soil, respectively. Also, correlation between boron contents of soil and boron contents of leaves is significant at the 0.01 level according to statistical analysis (Table-3). Some researchers reported that microelement content of soils have effected the microelement content of leaves[10,30,31].

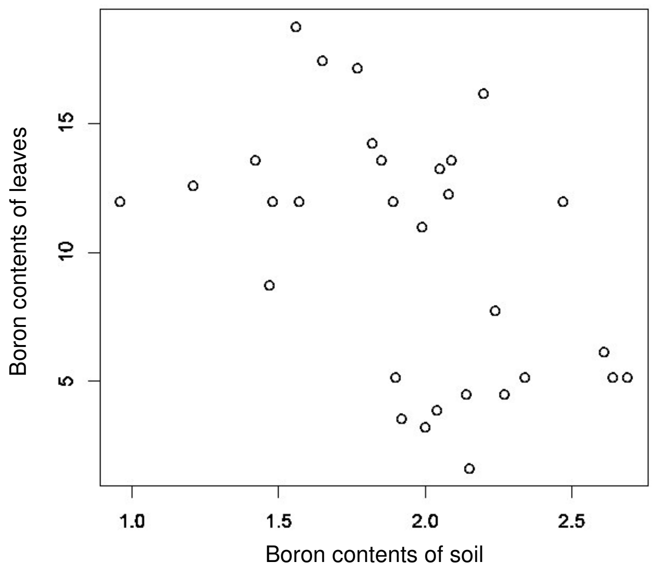

Fig. 2. Correlation between boron in soil and boron in leaves

Boron contents of grains: Boron contents of grain samples were given in Table-2, respectively. The amount of boron contents of grain samples changed between 2.60 and 9.10 mg kg^{-1}. Sample number 6 contained the lowest amount of boron and samples number 29 and 30 contained the highest amount of boron. While boron content of sample number 6 is 2.60 mg kg^{-1}, boron content of sample number 29 and 30 is 9.10 mg kg^{-1}. There are an inverse relation between boron contents of leaves and grain, respectively (Fig. 3). Also, correlation between boron contents of grain and leaves is significant at the 0.01 level according to statistical analysis (Table-3).

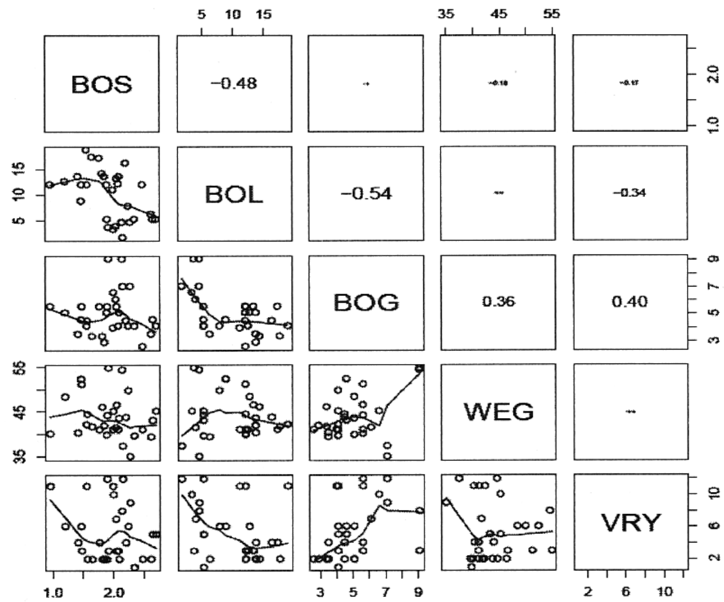

Fig. 3. Statistical Correlation between boron contents of soil (BOS), boron contents of leaves (BOL), boron contents of grain (BOG) and (WEG)

TABLE-3
CORRELATIONS BETWEEN BORON CONTENT OF SOIL, LEAF AND GRAIN ACCORDING TO STATISTICS ANALYSIS

	Mean	Standard deviation	N
Boron in soil	1.9490	0.41432	30
Boron in leaf	9.9267	4.87243	30
Boron in grain	5.0133	1.59411	30
1000 kernel	43.8080	4.86387	30

Correlations

		Boron in soil	Boron in leaf	Boron in grain	1000 kernel
Boron in soil	Pearson correlation	1	-.477**	-.039	-.177
	Sig. (2-tailed)	.	.008	.839	.348
	N	30	30	30	30
Boron in leaf	Pearson correlation	-.477**	1	-.538**	-.100
	Sig. (2-tailed)	.008	.	.002	.600
	N	30	30	30	30
Boron in grain	Pearson correlation	-.039	-.538**	1	.364*
	Sig. (2-tailed)	.839	.002	.	.048
	N	30	30	30	30
1000 kernel	Pearson correlation	-.177	-.100	.364*	1
	Sig. (2-tailed)	.348	.600	.048	.
	N	30	30	30	30

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Results were reanalyzed to determine optimum statistical models. For this aim, linear regression analysis was performed between dependent variable (boron contents of soil), independent variable (boron contents of leaves and grain) and descriptive statistics analysis results were given in Tables 4 and 5. The significant value of F test was obtained 0.003 with SPSS software. The predictive model for boron content which can be explained by boron contents of soil (Y), boron contents of leaves (X_1) and boron contents of grain (X_2) is below:

$$Y = 3.083 - 0.059X_1 - 0.108\ X_2 \quad (1)$$

TABLE-4
DESCRIPTIVE STATISTICS ON BORON CONTENTS OF SOIL (BOS), BORON CONTENTS OF LEAVES (BOL), BORON CONTENTS OF GRAIN (BOG) AND WEG FOR 30 WHEAT SAMPLES

Plant part	Range	Minimum	Maximum	Mean	Standard error	Standard deviation
BOS	1.73	0.96	2.69	1.95	0.08	0.41
BOL	17.11	1.62	18.73	9.93	0.89	4.87
BOG	6.50	2.60	9.10	5.01	0.29	1.59
WEG	19.97	34.83	54.80	43.81	0.89	4.86

TABLE-5
SUMMARY OF STATISTICAL MODEL (95 % CONFIDENCE) FOR BORON CONTENTS OF SOIL (DEPENDENT VARIABLE)

Independent variable	Coefficients	Standard error	t	Sig.	Standard error	F	Sig.
Constant	3.083	0.355	8.696	0.000	0.355		
BOL	-0.059	0.016	-3.811	0.001	0.016	7.292	0.003
BOG	-0.108	0.048	-2.261	0.032	0.048		

BOL = Boron contents of leaves; BOG = Boron contents of grain.

In addition, micronutrient elements exhibit a profound significance for the condition of human health as much as they do for a successful production of crops. Because of its property, boron can be easily dissolvable in water and joined in soil. Etibank, a biggest mining company of Turkey, is the first place for boron reserves and production of boron minerals in the World. Therefore, Turkey has a remarkable potential for producing of boron fertilizers. Insufficient content of micronutrient elements in soil has a negative impact on the development of crops, which, in turn, affects human health. Similarly, micro element deficiencies like zinc and iron bring out some serious health problems especially in children at developmental age. In this respect, Countries where boron deficiency, based on responses to boron application, in wheat has been reported included Bangladesh, Brazil, Bulgaria, China, Finland, India, Madagascar, Nepal, Pakistan, South Africa, Sweden, Tanzania, Thailand, USA, USSR, Yugoslavia, Zambia. Reports of boron deficiency in wheat continue to come out of India[32]. The essentiality of boron to animals and human beings has not been identified, but it is essential for plants. Boron deficiency affects plant growth and yield, but substantial amounts of boron are toxic to plants and reduce plant yield[11]. Boron, an essential trace element, is often applied to agricultural and horticultural crops. The exact function of boron in the plant is not fully understood[12], but it does appear to play a critical role in cell wall structure[13]. Boron contents of soil and boron content in plant parts can be shown very different concentrations. Consequently, determinations of boron variations for boron contents of soil, leaves and grain are essential agricultural purposes and plant cultivation.

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